

Research to the Typical Defects of Crystalline Silicon Photovoltaic Cells based on EL Images

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Abstract

According to the electroluminescent imaging mechanism of crystalline silicon photovoltaic cells, EL images of four kinds of the typical defects that happened with high frequency in the course of the production in crystalline silicon photovoltaic cells, such as, black core, cracks, broken gate and over welding, etc, were analyzed with some emphasis in this article on the aspects of the characteristic, production mechanism, harm and resolution of those images, then the solution to defects is applied to productive practice of Yingli, indicating its availability in its performance, which would help us make better use of the detected EL images in production practices by means of the rapid and accurate recognition on various defects, in order to impel the development of production technology and enhance the benefits.

Key words

Crystalline Silicon Photovoltaic Cells; Electroluminescence Images; Defect; Analysis; Diagnose

Introduction

Solar, a new type of renewable energy taking advantages of inexhaustibility, green environmental protection greatly improves the development of photovoltaic industry. Although much effort has been made to boost production technique, but various defects in the production process with high frequency affects the quality of PV modules. In order to detect the position and causes of defect of solar modules timely and exactly, all kinds of detection methods continuously appear, such as, Ultrasound-Resonance Imaging Scans, Contact Resistance Scans, I-V Characteristic Detection, Photoluminescence Inspection and Electroluminescence Inspection; one of with all the advantages of contact-free, real-time, visualization and accuracy, infrared technique based on the principle of electroluminescence inspection is widely used in defect inspection.

Though the position and type of defects can be detected with rapidness and accuracy in order to make best use of the near infrared images, there are also some problems, for example, the uncertainty on the infrared image characteristics of defects, unawareness of the potential harm, the imperfection of disposal method and so on, which will bring some inconvenience in the course of diagnosis of defects and classification of defective solar-modules. First of all, four kinds of the typical defects have been selected in this paper, such as black core, cracks, broken gate and over welding, the EL images of which have been extracted from Yingli's production lines, and then the characteristics of images, the cause and the hazards of the defects have been investigated in details. On the basis of communication with the first-line technical staff of Yingli, the methods to deal with these defects have been summarized, following that the feasibility and validity in the practice of production is validated, reaching good effect. This article gives us some insight into the characteristics of defects, provides a criterion on judgement of the invalid way and defect locations of the solar modules, as well as the reference basis to formulate solutions, which has great significance to develop production and improve quality.

Imaging Principles of Images

EL imaging is to get the image by means of exploiting the principle of electroluminescence imaging. In the camera obscura state, when a forward bias is added to silicon solar cell and appropriate amount of current is injected into cell, the power is injected into silicon solar cell with lots of non equilibrium carriers, then the ground state atom distributed on both side of diffusion junction can be motivated and become motivated state. Due to the instable state of motivated atom, it is

inevitably disintegrated into the lower energy state, which makes the phenomenon of the spontaneous radiation. Lots of non equilibrium carriers injected into the diffusion zone will recombine and glow continually, sending out the 1000-1100 nm infrared light. Using a CCD infrared camera to capture these photons, the radioactive recombination distributed image of silicon solar cell is obtained. Its working principle were presented in Fig.1.

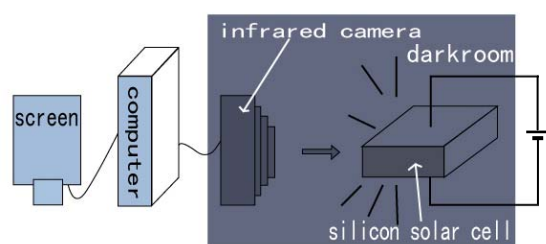


FIG.1 SCHEMATIC DIAGRAM OF EL TEST

Luminous intensity at any position of photovoltaic cells depends on the number of non equilibrium carriers and their combination pattern, the positions of the defects and luminous flux, etc. Under the influence of the external bias voltage, non equilibrium carriers have not been evenly distributed in crystalline silicon photovoltaic cells, which will cause the heterogeneity of the images of light-emitting dots. The defects information of crystalline silicon photovoltaic cells can be acquired depending on the extent of the negative exposure.

By the acquisition of image for analysis, the defects of crystalline silicon photovoltaic cells can be found effectively, mainly including: black chip and slip line caused by the raw material; antireflection film plating back, peripheral etching incomplete and grating scratch caused by solar cells manufacturing; three kinds of defects caused by poor packaging technology, including broken gate, cracks and debris, empty solder and over welding. In this paper, four kinds of those defects have been selected to make an emphatical analysis, such as black core, cracks, broken gate and over welding, etc.

Research the Typical Images of Defects

Defect Analysis of Black Core

As shown in Fig. 2, in the center of the EL image, large black area with round shape can be observed. That is to say, in an energized state, there is not 1150 nm infrared light in the region, and this phenomenon is linked to the minority carriers concentration and called black core defect. There are two main causes of the

defect: firstly, in the preparation of materials, due to crystal pulling long hours and creation with natural ingredients which has more impurity, crystal themselves contains more impurities, which is likely to cause oxidation-induced stacking fault; Secondly, during single-crystal preparation, the great thermal elasticity stress resulting from the higher crystal temperature, is the main cause of the high frequency of dislocation. The dislocations generated during the growth period of monocrystal silicon, is the central cause of black core, leading to the formation of the recombination centers of minor carrier in silicon substrate, shortening the life of minor carrier, and reducing the concentration of minor carrier, and causing the rise of apparent resistivity at the centre area of the cells, thus reducing the efficiency of solar cells markedly. As long as the black core piece is uncovered, it should be cleared and remade immediately, because it is unqualified. So the solution to these black core defects during the production of devices is to improve the growth process, in order to ensure that the dislocation density does not exceed 3000 per square centimetre; and cut the dislocation out after the conduction of dislocation tests.

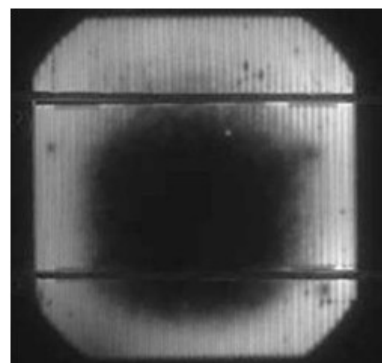


FIG.2 EL TEST OF THE "BLACK HEART" CELL

Defect Analysis of Cracks

As shown in Fig. 3, this infrared image appears bright gray in aggregate, and a very clear oblique line on the bottom is cracks of the cells, which can not be seen in visible light. Cracks defect is formed mainly in the process of welding and lying, or results from pre-bending and twisting of the silicon chip. Moreover, cracks will be introduced into the process of lamination and curing, even in the process of solder and cascade. In the cracked parts of solar cells, with the increasing defect densities, the minor carrier recombination velocity speeds up but reduces its life time. At the same time, this causes a dramatic increase in series resistance of the solar cell and a decrease in short circuit currents and filling factor. Though the

cracked defects are not readily observed, the harm is great. In the making of component, it will result in many problems, such as pieces and generation of hot spot, then reduction of the efficiency of producing power, even shortening the life and reliability of the solar cell; After the making of the components, the cracks will accelerate the decline in the power of the cells, reducing output power, and it is possible to expand the range of the cracks even leading to opening in mechanical loading conditions (Crack lengths greater than 1mm cannot tolerate pressure exceeding 2400 Pa). If a new crack is found, we must clear this cell and check the preceding working procedures in order to eliminate the faults.

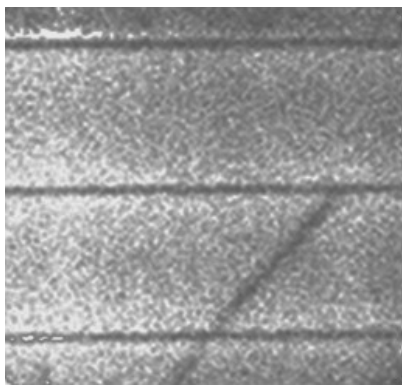


FIG.3 EL TEST OF THE CELL CRACK

Defect Analysis of Broken Gate

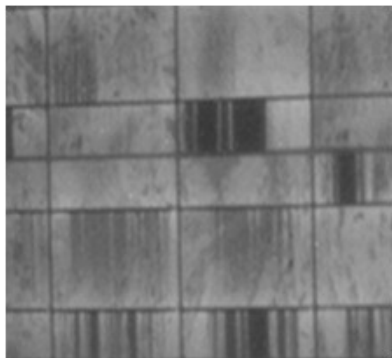


FIG.4 EL TEST OF THE BROKEN GATE CELL

As shown in Fig. 4, in this EL image, the shadows or dark patches of different sizes by the side of the door are broken gate defects. This defect, derived mainly from the screen printing processes and partly from the part of welding or laminating, belongs to the defects in workmanship. If the grating in a certain area breaks, external electric field is unable to reach the p-n junction, here, the location of broken gate on the EL image will be shown in gray because the density of excited photon decreases in that location. In practice, the defect can lead to reducing the collecting efficiency of photo-generated charge carriers, thus affecting

directly its spectral response and reducing the efficiency of solar cells. Broken gate comprises vice grid line fault and main grid line fault. About the vice grid line fault, if only a few grids break, it will have minimal effect on the module, but if the vice grid line fault occurs consecutively, the efficiency of electricity generating will also decline sharply, so it must be avoided; while about the main grid line fault, if it occurs, the entire battery will not work as they usually do. The first thing to do once broken gate defect is uncovered is to send the information to the production department, then the sizing is reformulated by means of diluting or updating the screen stencil and other potentially problematic parts. All those solar-modules with broken gate defects should be classified. If the accumulated defects area of a solar cell is no more than 5 percentage, the number of the defective cells is no more than 5, and the module should be classified as high-class product; while if the accumulated defects area of a solar cell is 6~8 percentage, the number of the defective cells is 6~9, and the module should be classified as second-class product; if the accumulated defects area of a solar cell is no more than 8 percentage, but the number of the defective cells is not less than 5, and the module should be classified as nonconforming product.

Defect Analysis of Over Welding

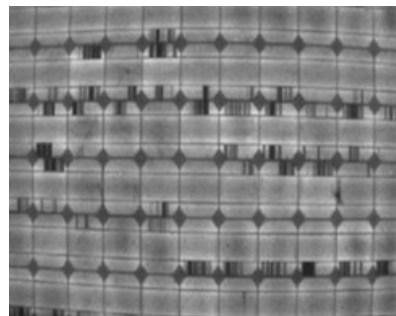


FIG.5 EL TEST OF THE OVER WELDING CELL

As shown in Fig. 5, in this EL image, the shadows extend from the edge of the main grid line to the opposite sides of the silicon solar cell along the direction of the vice grid line. There is nothing here but completely dark shadow in the outer regions of grid line generally. There are two kinds of shadow among the grid lines: one is the completely dark shadow, and the other shadow is transit from light to dark. The over welding defect of solar cell generated at the edge of the main grid line, is generally produced from welding process, which can cause the fine grid line to more easily slip off or crack the crystal. No light is emitted at the location of over welding on the EL image, due to

the absence of current. This defect will have an impact on the efficiency of electricity generating, and lower the power of module, even generate EVA layering in the location of over welding for a long time. The over welding piece has degrees which may be determined by the area of the black area. If the area of the shadow is no more than 5 percentage, the module shall be classified as qualified product; but if the area of the shadow is large, it will be exchanged. When the broken gate defect is detected, we must check and adjust the part of welding process, better welding temperature and optimize welding technique.

Conclusions

This paper firstly introduces the electroluminescent imaging mechanism, following the method to detect the defects of the solar cells based on near infrared detecting technology in directly perceived ways. In combination with the EL images, the focus of this article is on four kinds of defects occurring frequently in the course of the solar cells, such as, black core, cracks, broken gate and over welding, etc, by means of the analysis on the characteristic, production mechanism, harm and resolution of those images, then the solution to defects is applied to productive practice of Yingli, which has received good effect. In practice, it can be applied to better work on the detection of EL images, and perfect quantification targets as well as improve production technique and component quality, and guide the actual production.

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near infrared detecting technology.

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cell, solar module and junction box.

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